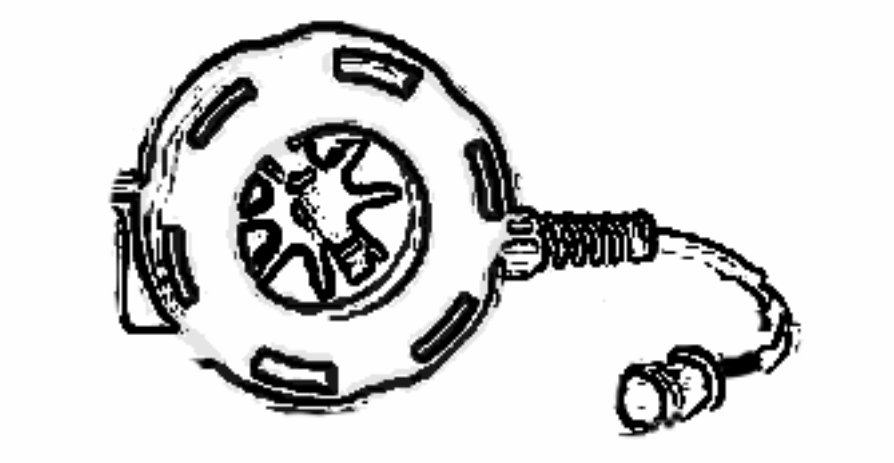
2010 Mechatronics

Higher

Finalised Marking Instructions

1. **(a)** Any flow sensor such as an impellor/paddle type flow meter could be used. Most flow sensors are sensing fluid flow but other types of flow could also be sensed. **1**

(b) The flow causes the impellor to turn and the turning causes a pulse to be generated which is sensed and counted, the number of pulses can be converted to give an indication of the flow rate.



Or other suitable sketch and brief description of the flow sensor chosen in part (a). 1 mark sketch + 1 mark description **2**

(c) This type of meter could be used in a fuel delivery line or a cooling/heating circulation system to indicate/measure flow rate.

Or other appropriate applications to match sensor chosen in part (a). **2**

2. **(a)** **Row 1 is correct**

Row	Element A is the …	Element B is the …	Element C is the …
1	**Data bus**	**Microprocessor Unit**	**Memory Unit**
2	Data bus	Memory Unit	Microprocessor Unit
3	Address bus	Microprocessor Unit	Output Unit

2

Table Q2(a)

(b) **Statement 2 is correct:** On a data bus the data flow is bi-directional. **1**

(c) A PLC is relatively easily changed by reprogramming without device replacement. Modular design allows addition/removal of elements.

Or any other two clear advantages that a PLC has over an ASIC. **2**

3. **(a)** **(i) & (ii)**

Decimal	Code name = **Natural or Pure Binary**	Code name = **Gray code**	Code name = **Binary Coded Decimal**
0	0000	0000	0000 0000
1	0001	0001	0000 0001
2	0010	0011	0000 0010
3	0011	0010	0000 0011
4	0100	0110	0000 0100
5	0101	0111	0000 0101
6	0110	0101	0000 0110
7	0111	0100	0000 0111
8	1000	1100	0000 1000
9	1001	1101	0000 1001
10	**1010**	**1111**	0001 0000
11	1011	1110	0001 0001
12	1100	1010	0001 0010
13	1101	1011	0001 0011
14	1110	1001	**0001 0100**
15	1111	**1000**	0001 0101

4

Table Q3(a)

(b) $1080 \times 1{\cdot}5 = 1620$ **1**

4. **(a)**

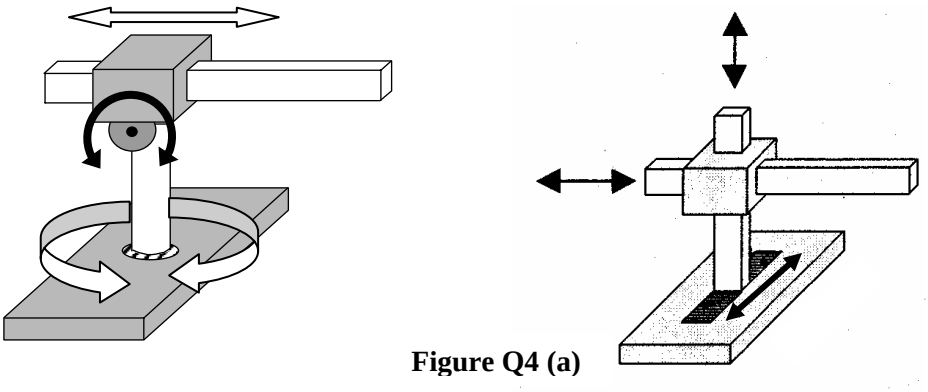
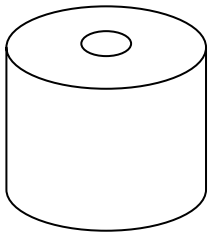


Figure Q4 (a)

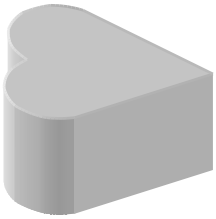
Polar **Cartesian or Rectangular**

(0.5 marks for each correct name) **1**

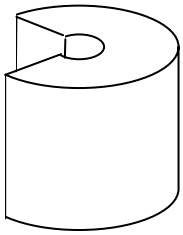
(b)



A cylinder



A 3D heart or
3D Cardioid shape



Or could have a cutout

Or a 3D
Kidney shape

Or other suitable 3D shapes. **2**

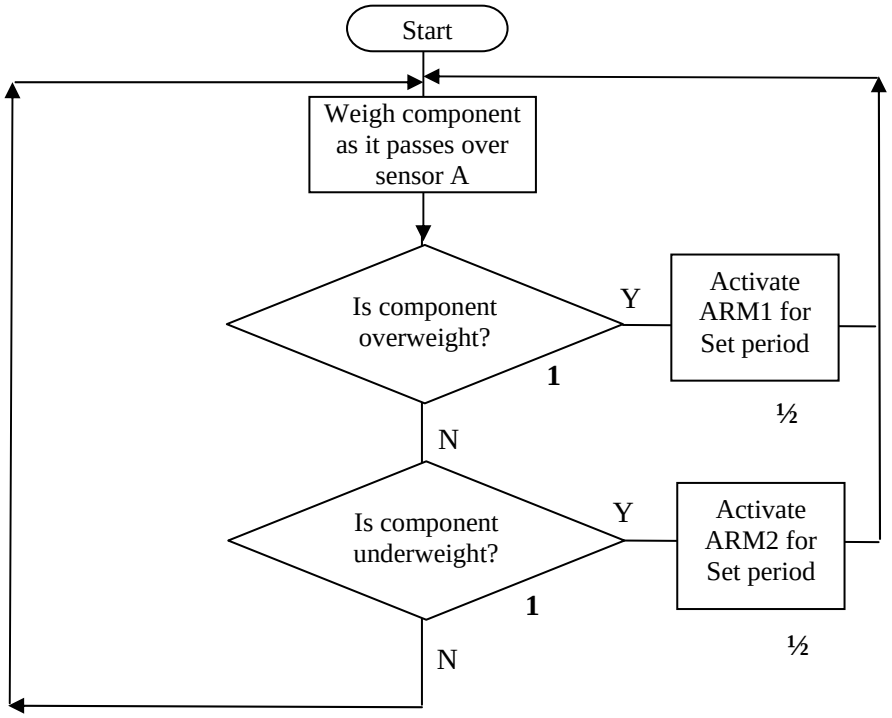
(c) Lead by nose is where the robot is manually lead through a process and numerous points recorded and the speed entered and the robot will playback the recorded movements. Point-to-Point is where the various key points are entered and the robot is allowed to calculate the actual movement betweens these points at the required speed.

Or other suitable explanation of the key differences. **2**

5. When the start contact (X0) is energised the timer is started and the output Y0 is also activated through the NC stop button (X1).
Y0 output energises the Y0 contact and forms a latch which maintains the output Y0 on when the start contact (X0) is de-energised. (START button released).
The timer counts for the required time and once 30 seconds have been reached, T0 is opened and Y0 output is de-energised.
If at any stage during the cycle the NC stop button (X1) is opened, the Output Y0 is de-energised breaking the latch (Y0) and resetting the timer.

Or other suitable description of the operation. **5**

6. (a)



(1 mark per decision, 0.5 mark per action box = 3 marks)

Note: if action boxes just says "Activate ARM" then there must be a "deactivate ARM" at a later stage or a blanket "deactivate or reset all ARMs" above the first decision. If not then ARMs will be left activated by previous decisions and errors will follow – failure to take account of this should result in reduced marks being awarded.

Note: the initial conditions are not given and any solution must reflect the assumed conditions made by the candidate. The flowchart is for continuing operation and the flowchart should reflect this by appropriate looping.

Or other suitable flowchart with correct functionality. **3**

(b) An optical beam prior to the entry into the correct weight box and each time the beam is broken the count is increased by one. This count can be stored electronically and a signal generated to a suitable display panel mounted above the sorting system.
The hardware required is a sensor, counter system, display system and a suitable controller system to enable the input & output signals/data to be handled.
(1 mark for parts, 1 mark for operation).

Or other suitable methodology and parts listing. **2**

7. **(a)**

Row	Figure Q7(a) represents ….	Figure Q7(b) represents ….
1	an OPEN LOOP control system response	a PID control system response
2	**a PID control system response**	**an ON/OFF control system response**
3	an ON/OFF control system response	an OPEN LOOP control system response

Row 2 correctly describes the type of control response

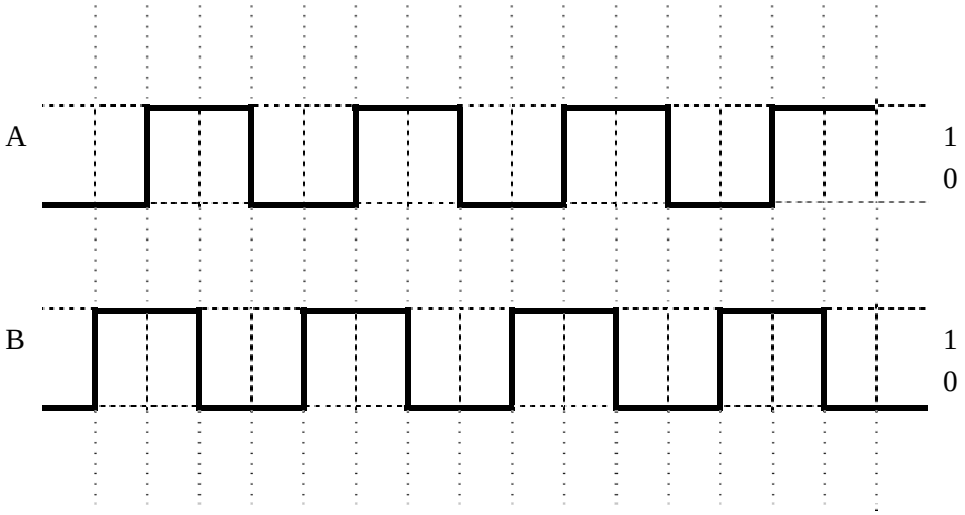
2

(b) P – Proportional action is associated with the **Error Signal**. The controlling action is in proportion to the difference between the desired value and actual value (the error signal) at any time.
I – Integral action is associated with **Offset**. The integral control action seeks to reduce the steady state offset to zero.
D – Derivative action is associated with **Response Time**. Derivative action modifies the speed of response.

Or other suitable brief descriptions. **3**

8. **(a)** Waveform Set 2 **2**

(b) Waveform showing sensor B leading sensor A



2

(c) A Hall type sensor or non-contact proximity sensor.

Or other suitable sensor. **1**

9. **(a)** An optical proximity sensor set to a suitable distance would be appropriate for this application. A light curtain or ultrasonic sensor could also be an appropriate solution.

Or any other suitable sensor for application. **1**

(b) A small positive displacement pump driven by a stepper motor on which the number of turns may be controlled. The required pulses could be sent to the stepper motor to ensure the correct number of turns are carried out by the pump to deliver the required volume of liquid.

Or other suitable answers which allow both counting and control. **2**

(c) Various appropriate answers would be accepted that may include counters of the number of times soap dispensed subtracted from 500ml volume, net weight detection ie changes in weight of liquid soap assuming fixed cartridge weight, optical measurement or level detection. **2**

10. **(a)** E a thermocouple

(b) C level

(c) E provide motion

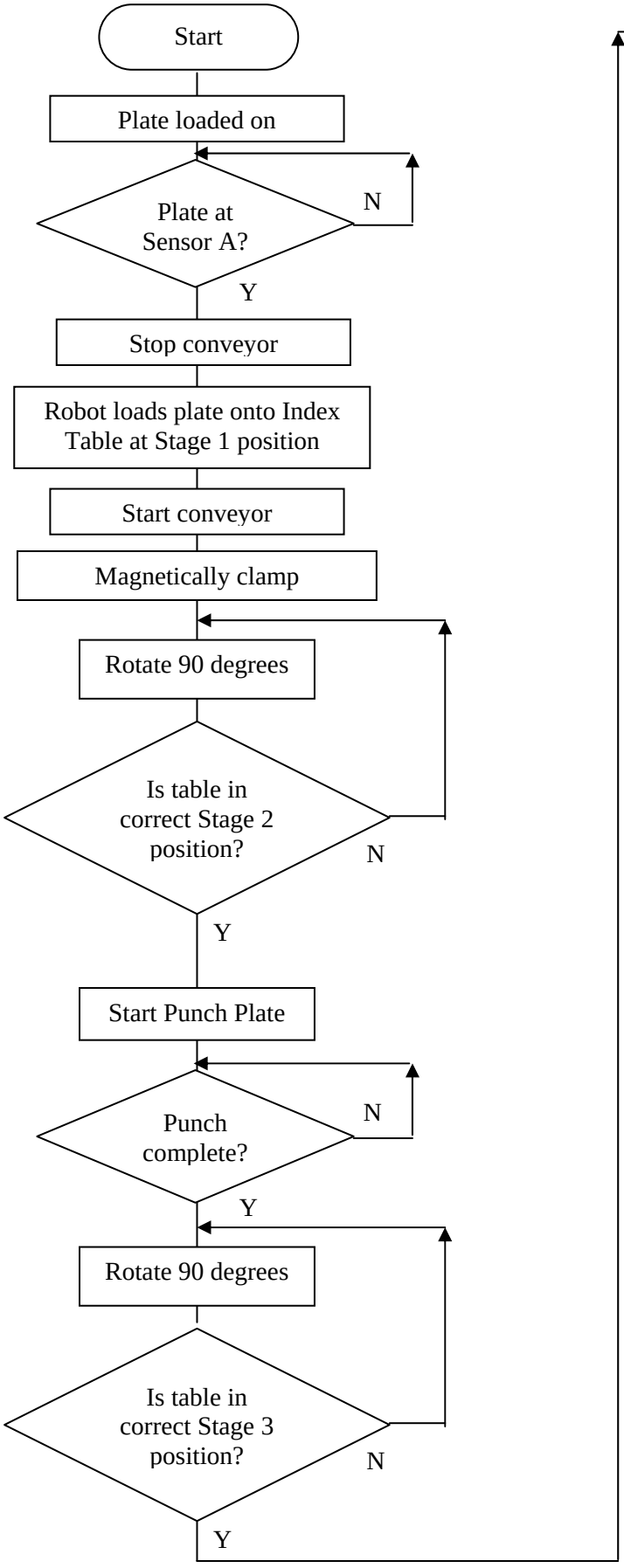
(d) E reprogrammable

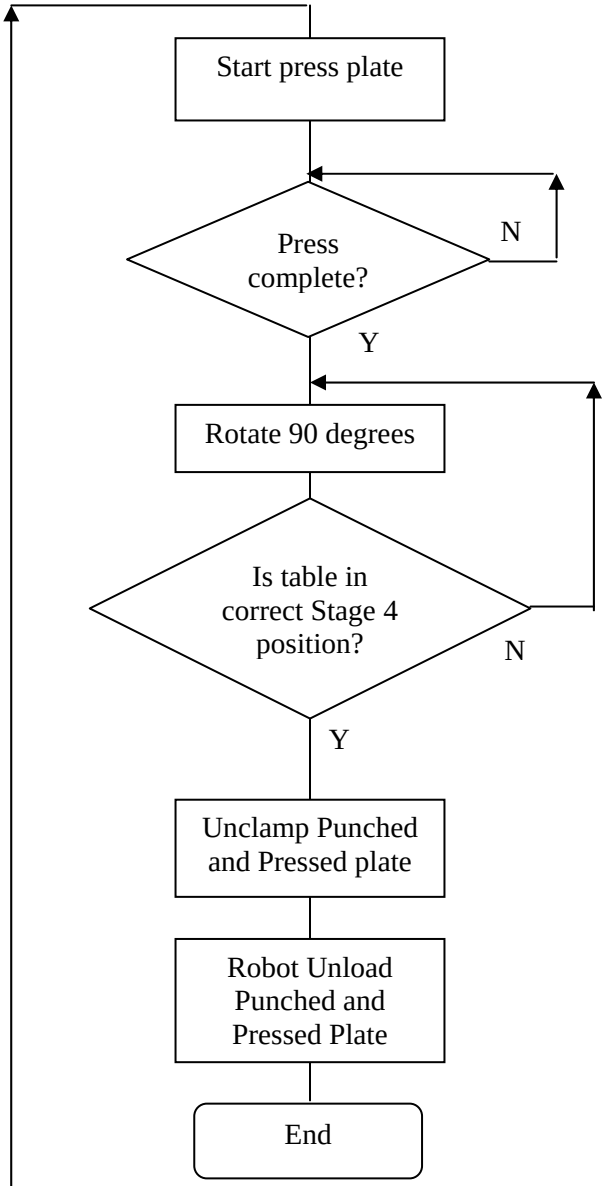
(e) B a coding system **5**

11. **(a)** It is unlikely that an optical beam and detector shining a beam across the conveyor would work well owing to the thinness of the plate (it is thin enough to be punched into shape). If the plate was more reflective than the conveyor then an optical system might work so that when the beam is reflected a signal is passed to the controller which stops the conveyor at the required position. When the plate is removed the signal changes and so enables the conveyor to restart.
However, since we know the material is "magnetically clampable" then a Hall effect device or other inductive sensor might prove a better choice. When the signal from the device changes, this is passed to the controller which stops the conveyor at the required position. When the plate is removed the signal changes and so enables the conveyor to restart.

Or other suitable answer thoughtfully presented and described sufficient for 3 marks. **3**

(b)





Although there are 6 decisions and 10 actions boxes there is considerable repetition.

The mains elements are

- Load & Unload Plate (1 mark)
- Stop and Restart Conveyor (1 mark)
- Clamp & Unclamp Plate (1 mark)
- Punch/Press Plate & complete (1 mark)
- Rotate Table 90 degrees (1 mark)

Correct sequence of repetitious elements (1 mark)

Total = 6 marks

(c) Advantage – high power available producing a large force in the press unit.

Disadvantage – high maintenance due to leaks etc.

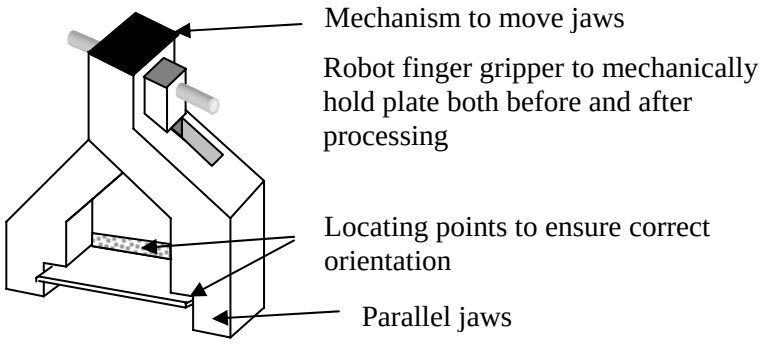
Or other suitable answers **2**

(d) Any two suitable answers such as 2 from those below

Moving automated machinery – appropriate guards and fencing system.
Programming robot – ensure teach pendant with safety cut out is used
Ways of stopping system if problems – Emergency Stop buttons strategically placed

Or other suitable answers which contain both the safety issue and the potential resolution. **4**

(e) A magnetic (owing to material being magnetically clampable), vacuum or finger type gripper could be used but it must allow for the correct orientation of the part when placed on the table. Vacuum could have a problem with finished part as it has slots punched into it.



Or other suitable solution. **3**

Note: only a labelled sketch is required and no description/explanation is required.

(f) A rotary encoder mounted directly to the Rotary Index Table with a suitable number of tracks to allow for plus or minus one tenth of a degree accuracy.

Resolution required = 360 degrees within two tenths of a degree
= 360 * 2/10 = 1800 positions
10 bits = 1024, 11 bits = 2048 positions so 11 bits needed.

This assuming encoder is directly connected (ie not gearing down) and a uniform code distribution.

Note: It could be possible for a solution using a non-uniform code distribution with a high resolution near the 0˚, 90˚, 180˚ and 270˚ station positions and a much lower resolution in between (eg 1.0˚ to 89˚, 91.0˚ to 179˚, etc). This would reduce the overall number of different codes needed. Any candidate who presented such a solution or any other workable solution with appropriate clarity and calculation should, of course, not be penalised.

(g) Input Signals

Table position
Sensor A (Part On conveyor)
Punch completed signal
Press completed signal

Output Signals

Punch signal
Press signal
Table drive (rotate by 90 degrees)
Magnetic Clamp (4 off)

(0.5 marks per input/output) **4**

12. **(a)** Any suitable temperature sensor that would suit the arduous conditions. For example a thermocouple. A thermocouple consists of a small bead of two different metals welded together, this junction causes a small voltage (mV) to be produced (Zeebeck effect). This small voltage is proportional to the junction temperature and thus is an indication of the temperature produced. This voltage can then be passed to the control system to control the power to the heaters.

Note no sketch required.

Or other suitable solution. **2**

(b) The system should either sense directly on the belt or indirectly on the drive system to the belt. If directly that for example a simple optical beam could be broken by a series of indents or slots in the belt causing a pulse to be generated. To get a suitable resolution to obtain the accurate control then there needs to be sufficient holes per metre. This rate (frequency) of these pulses can be converted to a linear speed. If sensing is done indirectly (eg, sensing of the rotating shafts or motor) then there needs to be a translation to take account of the rotary to linear transition. Any system must be able to provide suitable resolution for the 0.2m/s control – holes spaced at 10mm for instance would be unlikely to be sufficiently close together. All the needed elements need to be included to match the proposed solution.

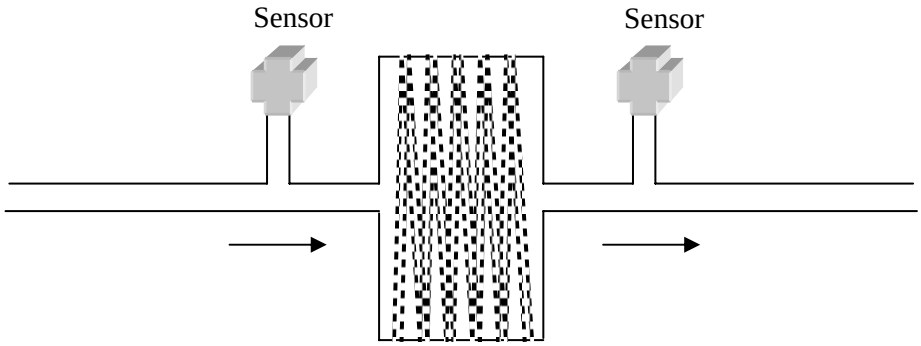
Or any suitably described sensing system **4**

(c) Input Signals
- Temperature Sensor
- Belt Speed
- Filter Condition

Output Signals
- Belt Drive
- Re-use Pump
- Heaters

Candidates may include the Touch Screen as Input and/or Output also. **3**

(d) A suitable pressure differential switch which is connected across the filter would indicate the filter condition and allow for control decisions to be made.



A solution that suggested removing the filter and then making comparative weight or optical density measurements would need to ensure that there are suitable isolation provisions made whilst this is carried out. However any system with a replaceable filter element would need this (or system shut-down) with perhaps hot standby switchover so failure to mention this aspect should not be penalised relative to other factors.

Or other suitable sensor system. **3**

(e) Hardware – level sensors, storage unit, pump system, heater and appropriate pipework, valves, etc.

The system would need to monitor the level of the Heated Oil Bath using a level sensor. When the sensor detects the oil has dropped to a preset low value using a comparator then it will automatically pump in the required amount of additional oil to bring it back to the correct level in the Heated Oil Bath from a storage tank. It would be best to preheat the oil to prevent adding cold oil to the system.

A suitable alternative may have a preheated header tank which gravity feeds heated oil based on a valve controlled by a level sensor.

Or other suitable system, parts and detailed description. **6**

(f) **(i)** Any two suitable safety hazards such as
Hot oil – ensure appropriates guards are in place.
Fire Hazard – ensure suitable venting and emergency stop system.
Moving belts and trapping points – guards and autostops.

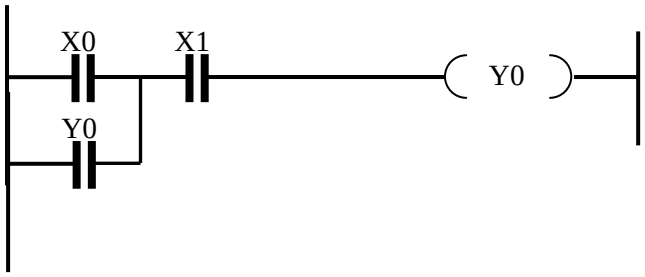
Or other suitable answers which include the hazard and how each will be addressed at the design stage. **4**

(ii) Any two suitable practical hazards such as
Dirty environment – suitably robust sensors, switches must be used.
Maintenance – the system should be designed to allow for the easy replacement of faulty parts.
High temperatures mean sensors and wiring must be able to reliably operate.

Or any other suitable hazards. **3**

13. **(a)** When Pushbutton (X0) is pressed, then provided the Paper cage sensor (X1) shows the Paper cage is in place then the Motor runs (Y0). **1**

(b)



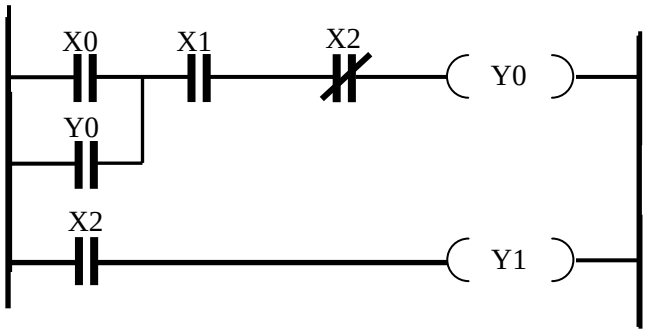
(1 mark for type of contact Y0 and 1 mark for ensuring ONLY the start contact is bridged, not the Paper guard sensor)

Or other suitable solutions that work correctly. **2**

(c) When the paper cage is removed then Paper cage sensor (X1) will open and the motor (Y0) will stop and the latching contact (Y0) will also open. When the paper cage is put back then the motor (Y0) will NOT start again unless the Start button (X0) is simultaneously being pressed.

Or other similar explanation **2**

(d)



The system description explains that when the "Motor overloaded" sensor (X2) detects an overload then it activates. To stop the Drive motor, a normally closed (X2) contact is placed in the first rung. Normally it is closed and the system operates as previously described with X2 having no effect. But when motor has overloaded then it breaks the first rung and stops the motor. When this occurs then the motor overloaded contact (X2) in the second rung operates and illuminates the warning light using the "Warning light"(Y1) output.

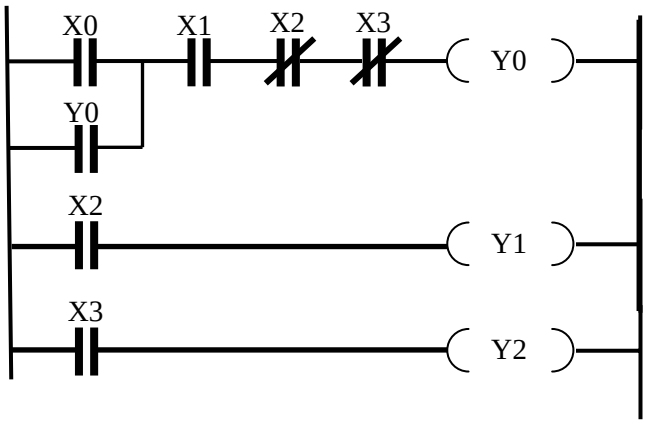
Note: this solution has the benefit that IF the motor overloaded contact resets itself then the system will not restart unexpectantly because the latching contact Y0 will open when the motor stops.

Or any other working solution but note the issue regarding the placing of the contact relative to the latching contact in this safety driven aspect of the program operation. **6**

(e) **(i)** Any suitable one sensor stated such as a load cell or a light curtain.

Note: the load cell would deal with issues of fullness being defined by "weight" and the light curtain would deal with fullness being defined by "volume". As this is a 1 mark question then either (or both) understandings of "fullness" would be acceptable and hence appropriate sensors choices. In practice both issues might need addressing but this is beyond the scope of the question. **1**

(ii)



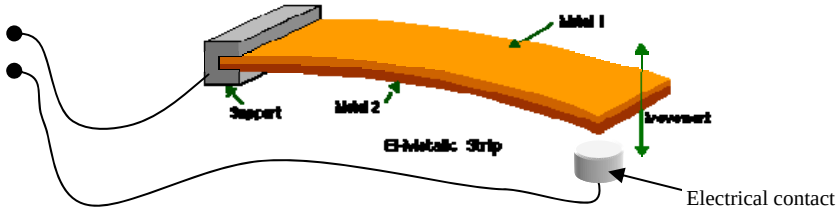
Or other suitable solution – note no description or explanation needed, it is only required that the system works correctly. **3**

(f) **(i)** Any suitable sensor such as a tactile sensor (eg microswitch) or a simple plug and socket arrangement.

Microswitch – the physical slotting in of the cage mechanically operates the microswitch and sends a signal to the system.
Plug and socket – a plug on the paper cage has wired connections between certain pins. When the cage is slotted in then the plug locates in a socket and completes a circuit sending a signal to the system.

Or other appropriate sensor and brief description. **2**

(ii) Any two types of temperature sensor suitable for incorporating in the motor. Examples include thermistor, thermostat (bimetallic strip), thermocouple.

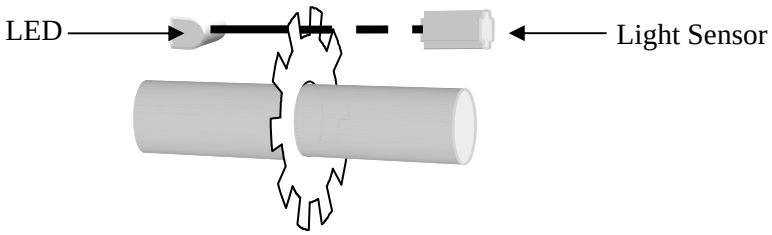


Bi-Metallic Strip – the two metals expand differently for a given temperature rise which results in bending which then operates the electrical contact.

Or other appropriate 2 sensors and brief description (note: a sketch is NOT required, 2 sensors need naming but only a brief description of operation of ONE of the sensors is required.) **3**

(g) Any suitable system addition with brief description and sensors sketched.

For example – The Shredder motor and/or the Cutters could be fitted with a slotted or toothed wheel. Rotation could be detected by an LED and light sensor. If rotation stops, indicating a jam, then the stream of pulses will cease and the PLC can detect this change in the signal. The PLC can then take appropriate action.



Note: the shredder may rotate in either clockwise or counter-clockwise directions with the additional rotation direction being included to help clear jams. However, it is desirable to detect jams regardless of direction of rotation and hence the simple system suggested.

Or other suitable solution that addresses the issue of detection of jamming. **3**

(h) Any suitable safety issues such as two from the following

Need to restrict access to the area
Need to cover the entrance to the shredder shoot to prevent things/people falling in/out
Need to prevent non paper materials entering the system
Need to provide a way of stopping system in an emergency.
Need for instruction and trained operator use only.

Or other suitable answers

Note there is NO requirement to suggest solutions here, only the issue. Any student offering solutions (eg emergency stop buttons) should not be penalised provided the safety issue being addressed is clear. **2**

[END OF MARKING INSTRUCTIONS]